FLUCTUATIONS IN ABUNDANCE OF COLUMBIA RIVER CHINOOK SALMON, 1928-54

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United States Department of the Interior, Fred A. Seaton, Secretary
Fish and Wildlife Service

FLUCTUATIONS IN ABUNDANCE OF COLUMBIA RIVER CHINOOK SALMON 1928-54

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ABSTRACT

The U. S. Fish and Wildlife Service is legislatively charged by the Coordination Act of 1934 as amended August 14, 1946, to investigate Federal water-use influence on the fishery and to provide for the protection of these resources. This is an evaluation of the Bonneville Dam influence on chinook salmon populations in the Columbia River based on the availability of the fish to the gill nets.

Breaking the fishing year into spring, summer and fall components, return estimates based on the periods before and after construction of the dam show mixed trends. The spring returns are better after dam construction, the summer returns are far worse, and the fall returns balance.

Ratios of return to escapement for the three seasons of the year show a spring improvement after dam construction, a large drop in summer, and a lesser drop in the fall. Return-to-escapement ratio levels after Bonneville Dam appear related to the proportion of chinooks which pass Bonneville Dam as adults and again as juveniles. For example, all summer chinooks spawn above Bonneville Dam while roughly two thirds of the spring chinooks spawn above the dam. On the other hand, the annual abundance curve reveals no change in trend before and after dam construction and the mixed trends of spring, summer, and fall seasons do not appear influenced by the construction date of Bonneville Dam.

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INTRODUCTION

Accurate evaluation of the effect on the fishery resources of large mainstream water-use projects of the Columbia River still remains a difficult and controversial problem. Attempts to measure the effects of water-use developments on the salmon runs have been only partially successful because direct effects are intermingled with the effects of other influences including the rapid encroachment of civilization on the natural, primitive habitat of the fish throughout most of the river basin.

In this study an attempt to measure the effect on the chinook salmon runs is made by analyzing the catch-per-unit-of-effort in the gill-net fishery of the lower river for a long series of years before and after construction of a specific water-use project, the Bonneville Dam. Although records since 1928 of catches of chinook salmon by gill-nets are available for the calculation of the catch per unit of effort in the fishery, certain influences should be taken into account which may slightly distort the index of abundance. Among these are (1) continued expansion of the coastwise troll fishery, (2) fishermen's strikes causing lapses in the data, and (3) suddenly reduced fishing ability of gill-nets such as occurred in 1940 when very low water in the spring and summer contributed to the bloom of a filamentous alga which clogged the nets.

This study is an extension and slight modification of an earlier work (Silliman 1950) which covered a period between 1935 and 1945. Here the data are extended back to 1928 from 1954 for a 27-year analysis. The returns are divided into three separate groups--spring, summer, and fall, and for comparison on these annual totals, the three seasons are presented in sum.

Grateful acknowledgment is made to D. R. Johnson, Supervisor of Research, Washington State Department of Fisheries, F. C. Cleaver, former Assistant Director of Fisheries, Oregon Fish Commission, and H. B. Holmes, Fishery Management Biologist of the Fish and Wildlife Service, for their review and suggestions in preparation of this manuscript.

GENERAL BACKGROUND

The following analysis is based on a sampling technique. In planning the analysis, certain limitations were required to keep the problem within workable proportions. One was limiting the analysis to catches of the most important species in the Columbia River, the chinook salmon, Oncorhynchus tshawytscha. A second was limiting it to the most consistently successful type of fishing gear, the gill nets. A third limitation used in the analysis was selection of a group of steady fishermen who would constantly provide data for comparisons based on paired weeks from adjacent years. A fourth limitation was the use of records only from gill-net fishermen who delivered their catches in the lower river. A fifth limitation was the assumption that a fisherman's ability to sample a population remained the same for two adjacent years. And the sixth and final limitation was the use of a test to identify fishing failures, which will be explained later in this paper.

The gill-net fishery caught approximately 64 percent of the total chinook catch from 1927 to 1934 (Craig and Hacker, 1940) and increased to 70.7 percent from 1935 to 1946 (Johnson, Chapman, and Schoning, 1948). Some who deliver their catch in the lower river continue the employment of the original floater-type gill net. Mesh sizes for catching chinook salmon generally vary from 7 inches to 9-3/4 inches stretched measure (Craig and Hacker, 1940). Another type of net used in the faster current is the "diver" net which has sufficient lead to sink it to the bottom. A modification of the original gill net is the "trammel" net which uses a smaller mesh for catching a variety of sizes of fish. The "trammel" originating in about 1900 is used mostly as a "diver" type net.

The Columbia River gill-net boat used by

the gill-netters is 26-feet long, gasoline powered, and well known for its seaworthiness. Usually gill-net fishing occurs at night after which the fishermen make their deliveries to the various receiving stations in the morning. In spring the fishing may take place in daylight when the river is turbid.

Certain seasonal restrictions have been imposed on commercial fishing in the Columbia River to obtain larger escapements for maintaining future runs of salmon. In 1877 weekend closures were first established. By 1909, closed seasons existed from March 1 to May 1, from August 25 to September 10, plus a 24-hour closure on weekends during spring and summer. During the years 1943 to 1947, an additional closed period of May 20 to June 10 was established. In 1948 and 1949 the latter period was changed to June 15 - July 6 below Bonneville Dam, with a similar period established above Bonnevile Dam so staggered as to protect the fish, safeguarded by the closure below. Closures of similar length but slightly different timing have been continued in the May-June period. In addition, a July 15 to 29 closed season was established below the dam with a staggered period above, beginning in 1952.

CATCH-PER-UNIT-OF-EFFORT

Records of individual fisherman's catches, copied from the ledgers of a large fish packing company on the Columbia River, constitute the basic data from which the catch-per-unit-of-effort was calculated for each year. Only catch records from the season between May 1 and October 1 which normally accounts for 95 percent of the yearly catch of chinook salmon were used. These five months were divided into 22 weekly periods: weeks 1-4 involved fishing between May 1 to May 28; weeks 5-13 fishing between May 29 to July 30; and weeks 14 to 22, fishing between July 31 and October 1.

The catch records of only full-time fishermen were considered in the analysis, with the belief that they would sample the chinook salmon population better than part-time fishermen. The fishermen were divided into two groups. One group must have made one delivery each month in the period between May 1 and August 26. The other fished between September 10 and October 1. A total of thirty or more individual fisherman's records was the attempted goal, but in a few instances that many were not available.

The analysis is based on the assumption that a man's ability to sample the salmon population by fishing remained approximately the same for two comparable years. An ever changing list of fishermen's records was found necessary because fishermen were constantly dropping out of and entering the fishery. Use of such records was made possible by a chain-link system as used by Silliman (1950) in which catch records were paired by successive years, permitting a continuous analysis. Of interest are the records of two fishermen who were found to have fished for 25 years. Their catch records are plotted in figure 1 and resemble each other so closely as to indicate their fluctuations may stem from a common cause; the most likely such cause is fluctuation in the size of runs of salmon.

In comparing similar weeks of successive years, a non-fishing week was not weighted against a week in which a fisherman was engaged in fishing. However, the fact that a fisherman may have fished unsuccessfully, must be taken into consideration. In an attempt to decide whether a fisherman had fished for chinooks unsuccessfully or whether he had simply not fished, certain assumptions were made. First, it was decided that a fisherman would not continue to fish for three successive weeks unsuccessfully, but instead would quit until fishing improved or use a smaller meshed net for catching other species. Therefore, the rule adopted by Silliman (1950) was used: A fisherman is considered to have fished during a given week, even though he made no deliveries, if he made one or more deliveries during the preceding or succeeding week. In addition to this, it was felt that unless at least 10 percent of all the fishermen had made only one delivery during the week in question, it was not very likely that anybody had been unsuccessful. The following was therefore added to the rule above: (and) at least 10 percent or more of the fishermen making deliveries during the given week made only one delivery.

This rule was used with the full realization that some error would be introduced, but it did supply an approximation which would suffice for an analysis based on averages.

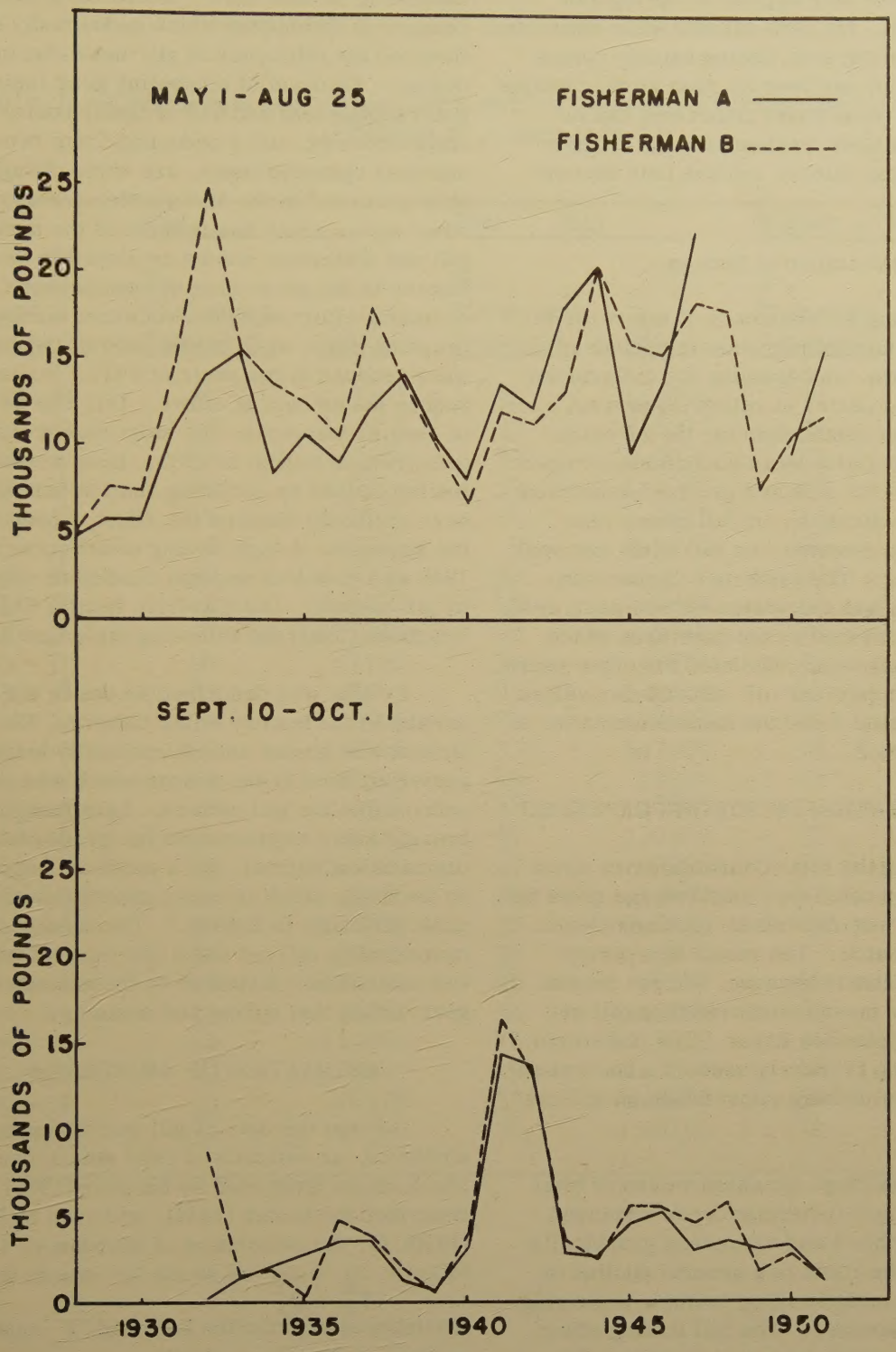

Figure 1.--Pounds of gill-net-taken chinook salmon caught by two fishermen, Columbia River 1928-1951.

The above rule applied to spring and summer fishing. No zero catches were estimated in the fall since chinook fishing usually comes to a standstill for the year as soon as the catches drop off to the point where fishermen can do better using smaller meshed nets for silvers (O. kisutch), and chinook catches thus become incidental.

Calculation of Indices

Assuming a consistency of effort for individual fishermen during similar periods of successive years, and applying the criteria for zero catches, a series of ratios (season n/, season n-1) was established for the 27 years, table 1. These ratios were obtained by comparing the catch of the selected group of fishermen for the spring, summer, or fall of one year with the spring, summer, or fall catch one year earlier or later. The catch-per- fisherman week in pounds was calculated for one year, 1940, which was established as the base upon which catches-per-unit were calculated for other years. Resulting catch-per-unit-of- effort index values are shown in table 2 and the same information is plotted in figure 2.

CALCULATION OF EFFORT EXPENDED

Dividing the total Columbia River catch (table 3) by this catch-per-unit average gives the number of gill-net-fishermen weeks employed in making the catch. The result is a purely hypothetical statistic because, for one reason, there are other means employed than gill net fishing in the Columbia River. The fishermen-week calculation is merely used as a convenient measure of total fishing effort based on gill net activity alone.

The resulting calculated values of total gill-net catch-per-fishermen-week employed are shown in table 4 and expressed graphically in figure 3. The trend is a general decline in effort with the most striking example occurring in spring and summer. The fall fishing effort has been more stable with an indication of decline in the last three years 1952, 1953, and 1954.

In search of reasons for a decline in effort expended in the Columbia River, some theorizing is done here. There have been some changes in techniques which undoubtedly have influenced the efficiency of gill-net fishermen to a degree. Removal of competing gear (seines and fixed appliances) and use of faster boats, mechanized rollers, and a reduction from two-man to one-man operated boats, are some changes which have occurred in the last quarter century. Another factor which has influenced the number of gill-net fishermen-weeks employed in the chinook fishery is the shortening of open seasons. Change of fishing effort expended occurred during depression years when prices paid to fishermen were reduced in the panic of 1932. Strikes also reduce the amount of effort. This can be verified in several instances--the most recent example occurring in August of 1952. Less profitable fishing caused by declining runs in June and July have obviously reduced the effort expended in the summer. A high fishing effort occurred in 1940 as a result of unusual conditions experienced by gill netters. Quoting from Pacific Fisherman Yearbook (1941) the following statement is made:

"May was described as one of the poorest months in the history of the fishery. The usual freshet was absent and exceptionally low water prevailed most of the season which was especially unfavorable for gill netters. Late June and July brought some improvement but production continued below normal; and a peculiar fungus growth on the nets, which is under investigation, caused great difficulty in fishing." The fishing effort measured by gill net catch-per-unit-of-effort was undoubtedly distorted by the success of other gear during that spring and summer.

ESTIMATION OF ABUNDANCE

From the data of gill-net-fisherman-weeks employed, an estimate of total return can be made. The formula first used by Baranov (1918), later described by Ricker (1944), and used by Silliman (1950), for the calculation of abundance, is as follows: $\frac{f_2}{f_1} = \frac{\hat{p_2}}{p_1}$ in which "p" equals the instantaneous exploitation rate and "f" equals the amount of effort expended.

To use this formula certain requirements must be met: (1) no significant natural mortality must occur during the fishing season, (2) the gear should be uniformly efficient, (3) the amount

Table 1.--Catch-per-unit-of-effort ratios between fishing seasons
(Season n / Season n-1)

Seasons Compared	May		June - July		August - September	
	No. Fishermen Compared	Ratio	No. Fishermen Compared	Ratio	No. Fishermen Compared	Ratio
1929-28	30	0.9707	30	1.2859	30	0.7916
1930-29	33	1.0544	33	0.6377	33	2.3867
1931-30	32	0.9584	33	1.2055	33	1.4553
1932-31	49	1.5956	53	1.6924	53	0.7309
1933-32	14	0.9546	14	1.0433	13	0.5154
1934-33	9	0.7369	9	0.4678	28	1.6407
1935-34	32	1.4435	32	1.4300	30	1.2353
1936-35	46	0.9317	46	0.7424	30	0.5901
1937-36	97	1.1878	97	.8714	46	1.3822
1938-37	94	.7721	94	.7571	39	.7851
1939-38	85	.7943	85	1.2613	45	1.2169
1940-39	74	.1905	74	.4498	84	1.0503
1941-40	55	3.2106	55	1.7588	68	2.0217
1942-41	49	.7513	49	.9294	79	.9796
1943-42	48	2.2384	48	.8888	92	.4693
1944-43	34	.5311	34	1.0324	72	1.5408
1945-44	27	2.1024	27	.3996	66	.9791
1946-45	24	.9966	24	.9680	42	.8129
1947-46	30	1.2483	30	2.0233	49	1.1843
1948-47	30	.9621	30	.7400	57	1.0412
1949-48	26	1.1121	26	.7188	59	.5460
1950-49	33	.6867	31	2.9724	63	1.0092
1951-50	41	1.9860	41	.9519	56	1.0711
1952-51	29	1.3982	29	1.0840	48	1.2499
1953-52	33	.6578	33	1.2080	54	.7322
1954-53	34	.9328	34	.9191	44	.7673

Table 2.--Catch-per-fisherman-week, Columbia River chinook salmon gill-net catches

Year	Pounds per fisherman-week for: May	June July	August September
1928	327	614	1,055
1929	317	790	835
1930	334	504	1,992
1931	320	607	2,899
1932	510	1,027	2,119
1933	487	1,071	1,092
1934	359	501	1,792
1935	518	717	2,214
1936	483	532	1,307
1937	574	464	1,806
1938	443	351	1,418
1939	352	443	1,725
1940	67	199	1,812
1941	215	350	3,664
1942	162	326	3,589
1943	362	290	1,684
1944	192	299	2,595
1945	404	119	2,541
1946	403	115	2,006
1947	503	233	2,447
1948	484	172	2,548
1949	538	124	1,391
1950	369	368	1,404
1951	733	350	1,504
1952	1,025	379	1,880
1953	674	458	1,377
1954	629	421	1,057

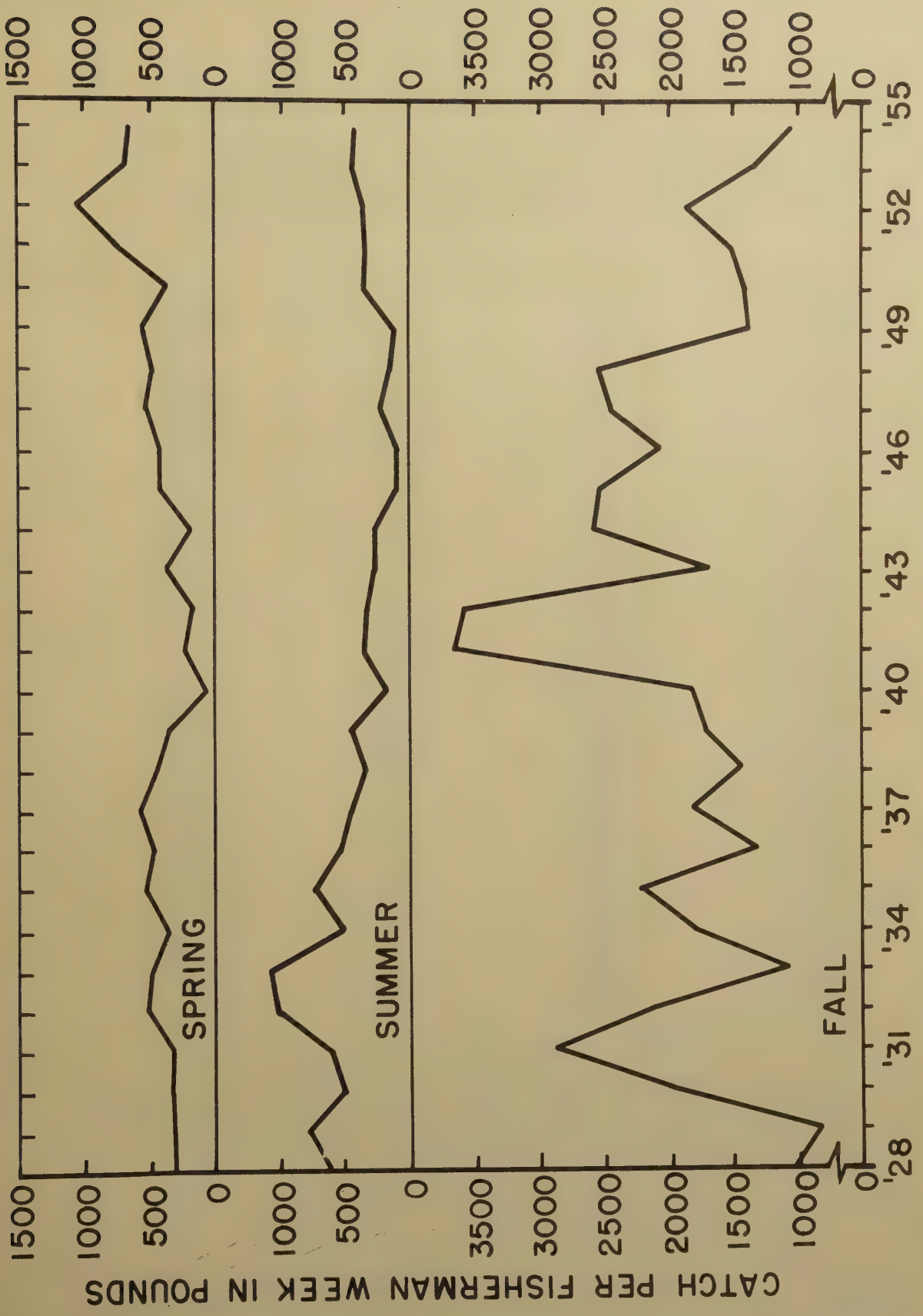

Figure 2.--Catch-per-unit-of-effort index values.

Table 3.--Landings of chinook salmon inside the Columbia River (by thousands of pounds).

Year	January-May	June-July	August-December
1928	2,204	5,111	9,126
1929	2,570	5,008	6,641
1930	2,920	4,188	9,078
1931	3,003	5,524	12,492
1932	2,567	5,534	7,735
1933	1,611	6,711	9,952
1934	1,638	4,992	11,781
1935	2,550	4,904	7,703
1936	2,111	3,661	10,129
1937	3,420	2,927	12,284
1938	1,734	2,187	8,492
1939	1,629	3,403	8,467
1940	792	1,868	10,856
1941	1,469	1,945	19,817
1942	1,110	1,452	16,098
1943	1,333	888	9,206
1944	1,079	1,165	11,833
1945	1,566	514	10,891
1946	1,235	456	12,603
1947	1,274	990	15,044
1948	1,983	639	14,731
1949	1,705	297	8,773
1950	1,311	433	8,551
1951	1,989	630	7,413
1952	2,912	703	3,567
1953	1,770	708	4,474
1954	1,454	599	3,331

Statistics 1938-1949 from Oregon Fish Commission, Cont. No. 16, September, 1951. All other catch figures obtained from Oregon and Washington Fisheries Departments but are not necessarily final official figures.

Table 4.--Calculated amount of fishing effort expended toward capture of chinook salmon inside the Columbia River in units of 1940 gill-net fishermen-weeks

Year	January-May	June-July	August-December
1928	6,740	8,324	8,650
1929	8,107	6,339	7,953
1930	8,742	8,310	4,557
1931	9,384	9,100	4,309
1932	5,033	5,389	3,650
1933	3,308	6,266	9,114
1934	4,563	9,964	6,574
1935	4,923	6,840	3,479
1936	4,371	6,882	7,750
1937	5,958	6,308	6,802
1938	3,914	6,231	5,989
1939	4,628	7,682	4,908
1940	11,821	9,387	5,991
1941	6,833	5,557	5,408
1942	6,855	4,454	4,486
1943	3,682	3,062	5,467
1944	5,620	3,896	4,560
1945	3,876	4,319	4,286
1946	3,064	3,965	6,100
1947	2,533	4,249	6,148
1948	4,097	3,715	5,781
1949	3,169	2,395	6,307
1950	3,553	1,177	6,090
1951	2,714	1,800	4,929
1952	2,841	1,855	1,897*
1953	2,626	1,546	3,249
1954	2,312	1,423	3,151

* Fishing interrupted by strike.

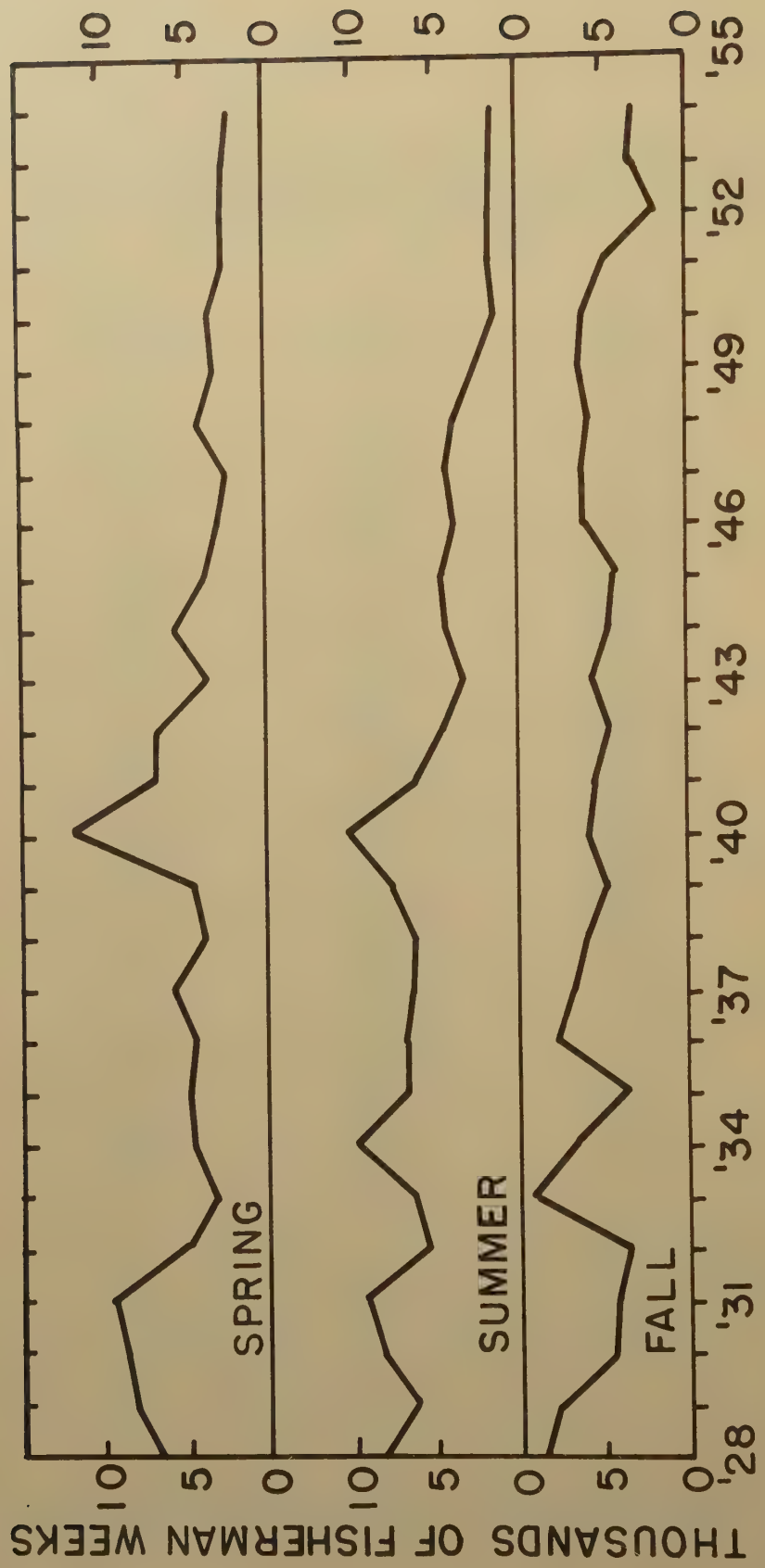

Figure 3.--Effort expended in Columbia River Fishery

of gear should not change within each season, and (4) a uniform pattern of arrival and departure of fish over the period of successive years is necessary. The second requirement regarding uniformity of gear is generally true. The net sizes and methods have remained relatively uniform. In regard to changing amount of gear within the season, some fishermen are exclusively fall fishermen, some fish in the spring only, and some in the spring and summer. Division of the gill-net years into three seasons minimizes the possibility of abusing this rule. The last rule concerning uniformity of arrival and departure is considered here. The chinook salmon migration is known to vary several days from one year to the next. Fishermen usually manage to have access to the peak of the spring wave of chinooks entering the Columbia River by fishing up or down the river on opening day.

Use of the Baranov formula requires a base year in which the absolute abundance of the return is known. With the commercial catch record and data on passage of fish at Bonneville Dam available this requirement is satisfied. Escapement to streams below Bonneville Dam is the unknown quantity. For this information biologists from the state fishery agencies were consulted. The year of 1947 was chosen for the base year because of better knowledge of average-weight data in that year than in others. In table 5 the best estimates of escapements to the various streams below Bonneville Dam are presented. These estimates are obtained from hatchery records, spawning censuses, and actual counts provided by the Oregon Fish Commission and the Washington State Department of Fisheries. They are known to contain error, but are the best estimates available and, as indicated by Silliman (1950), even large errors in such estimates would not invalidate the final conclusions.

A summary of the components of the returns, divided into the three seasons--spring, summer, and fall, is presented in table 6. The returns are converted into pounds by using Bryant's unpublished weight data. Commercial catch statistics were provided by the Oregon Fish Commission and the Washington State Department of Fisheries. Bonneville counts were provided by the Corps of Engineers.

From the information provided in the 1947 season, the seasonal fishing mortality "m" can be obtained. This is done by dividing the total catch in pounds for spring, summer, and fall by returns. Returns are determined by adding catch below Bonneville Dam plus escapement below Bonneville Dam plus Bonneville counts. Fishing mortality rates of 34.1 percent, 64.4 percent, and 77.6 percent for spring, summer, and fall were thus derived. Then by use of the formula $\frac{f_2}{f_1} = \frac{p_2}{p_1}$ in which "f" represents effort and "p" represents fishing mortality, one unknown "p" value is solved for--values of effort and the other "p" value being known. The known "p" value is derived from the fishing mortality "m" by Ricker's instantaneous mortality tables. The calculated "p" value is converted to fishing mortality rate "m" by the same table. The value of "m" is then applied to the Columbia River inside catches to determine the estimate of total returns. In the above equation f_2 and p_2 represent one year previous to f_1 and p_1. Fishing mortality and estimated returns based on catch-per-unit-of-effort of Columbia River gill-netters appear in tables 7, 8, and 9, and this information is plotted in figure 4.

INFLUENCE OF WATER-USE PROJECTS ON CHINOOK SALMON IN THE COLUMBIA RIVER

During the period in which the returns of chinook salmon are compared in this report, a great number of tributary water-use works and several main-stem multi-purpose dams have been constructed. Hydroelectric, irrigation, and flood control facilities in the tributaries have influenced the migration and natural habitat of the chinook salmon, but main-stem dams occupy more important migration routes and therefore are in a position to affect large numbers of chinooks.

Dams may influence the migration and natural habitat of the salmon by either blocking migration when no fishways are provided or by requiring the fish to ascend the facilities provided for them. Habitat is influenced by water storage behind dams which convert stream spawning areas to slow-flowing bodies of water unsuitable for spawning. Juvenile downstream migrants must make their way over spillways or through penstocks without special protection at large installations.

Table 5.--Estimated 1947 chinook salmon escapements to streams entering the Columbia River below Bonneville Dam.

Season and stream	(Thousands of fish) Oregon	Washington	Total
Spring, January 1 - May 31			
Willamette River	53		
Sandy River	1		
Willamette below Oregon City	3		
Cowlitz River		10	67
Summer, June 1 - July 31			
	0	0	0
Fall, August 1 - December 31			
Klaskanine River	1		
Bear, Big, Gnat Scappoose Creeks			
Clatskanine River	2		
Youngs River	1		
Sandy River	2		
Bonneville Hatchery	11		
Cowlitz River		30	
Alochomin River		2	
Grays River		1	
Coweeman River		3	
Kalama River		20	
Lewis River		5	
Washougal River		3	81
Totals	74	74	148

Table 6.--Estimation of return of chinook salmon to the Columbia River in 1947

(Escapements and Bonneville counts converted to pounds)

Segment of return:	Pounds of fish
Spring, January 1 - May 31	
Catch below Bonneville Dam in river (1,032,801)	1,033,000
Estimated escapement to streams below Bonneville Dam (15.8 average weight x 67,000 number)	1,059,000 1/
Bonneville count (12.3 average weight x 133,562 number)	1,643,000 2/
	3,735,000
Summer, June 1 - July 31	
Catch below Bonneville Dam in river (949,946)	950,000
Estimated escapement to streams	0
Bonneville count (15.1 average weight x 38,860 number)	587,000 3/
	1,537,000
Fall, August 1 - December 31	
Catch below Bonneville Dam in river (11,877,911)	11,878,000
Estimated escapement to streams below Bonneville Dam (21.9 average weight x 81,000 number)	1,774,000 4/
Bonneville count (18.6 average weight x 307,955 number)	5,728,000 5/
	19,380,000

1/ From an average weight of 12,545 fish caught below Bonn. Dam May 1947.

2/ From an average weight of 441 fish caught above Bonn. Dam May 1947.

3/ From an average weight of 161 fish caught above Bonn. Dam June, July, 1947.

4/ From an average weight of 17,445 fish caught below Bonn. Dam Aug., Sept. 1947.

5/ From an average weight of 1,997 fish caught above Bonn. Dam Aug., Sept. 1947.

All average weights from unpublished data collected by Bryant, F. G., former research biologist of the Fish & Wildlife Service.

Table 7.--Fishing Mortality and returns - January-May, 1928-1954
Columbia River chinook salmon

Year	Percentage Seasonal Fishing Mortality	Returns in 1,000 lbs.	Remarks from Pacific Fisherman
1928	67.4	3,270	
1929	74.1	3,468	
1930	76.8	3,802	Price 17¢
1931	79.2	3,792	Price 10¢
1932	56.8	4,519	Depression prices lower intensity.
1933	42.3	3,808	Strike-fishermen & cannery operators.
1934	53.2	3,079	Strike-season opened May 3.
1935	56.0	4,554	Washington eliminated traps & seines.
1936	51.8	4,075	
1937	62.8	5,446	Season opened early, April 26.
1938	47.8	3,628	
1939	53.7	3,034	
1940 1/	86.0	921	May poorest in history.
1941	68.0	2,160	
1942	68.0	1,632	Season slow.
1943	45.7	2,917	Good for a few days.
1944	60.6	1,780	
1945	47.3	3,311	Catches dropped off fast.
1946	40.0	3,088	
1947	34.1	3,736	Opened better
1948	49.3	4,022	Started well.
1949	41.1	4,148	Oregon eliminated traps & seines.
1950	44.6	2,939	In effect 1950.
1951	36.2	5,494	
1952	37.5	7,765	
1953	35.0	5,057	Early weeks contributed large share of total production.
1954	31.6	4,601	

1/ Gill net fishery poor sample of run in 1940 due to unusual condition of river.

Table 8.-- Fishing mortalities and returns - June-July, 1928-1954
Columbia River chinook salmon

Year	Percentage Seasonal Fishing Mortality	Return in 1,000 lbs.	Remarks from Pacific Fisherman
1928	86.7	5,895	
1929	78.6	6,372	
1930	86.7	4,830	Seines got larger share than usual.
1931	89.0	6,207	
1932	73.0	7,581	Lower prices lower intensity.
1933	78.1	8,593	
1934	91.1	5,480	Poor in July.
1935	81.0	6,054	Wash. eliminated traps & seines.
1936	81.4	4,498	
1937	78.6	3,724	
1938	78.1	2,800	
1939	84.7	4,018	
1940	90.0	2,076	Conditions unfavorable for gill netters.
1941	74.3	2,618	
1942	66.4	2,187	
1943	52.8	1,682	
1944	61.3	1,900	
1945	65.0	791	Poor return.
1946	61.7	739	Strike June 10-July 16.
1947	64.4	1,537	
1948	59.3	1,078	Floods closed part of season.
1949	44.0	675	
1950	24.4	1,775	
1951	35.0	1,800	
1952	35.6	1,975	
1953	30.9	2,291	
1954	28.8	2,080	

Table 9.--Fishing mortalities and returns - August-December, 1928-1954
Columbia River chinook salmon

Year	Percentage Seasonal Fishing Mortality	Returns in 1,000 lbs.	Remarks from Pacific Fisherman
1928	87.9	10,382	
1929	85.6	7,758	Poor escapement.
1930	67.0	13,549	Weak market, prices sharply cut.
1931	65.0	19,218	August greatest run on record; price decline to lowest on record, price declined to ½¢.
1932	58.9	13,132	
1933	89.2	11,157	Earnings of fishermen twice 1932.
1934	80.0	14,726	Heavy August runs.
1935	57.2	13,467	Fishermen's strike in August.
1936	84.9	11,930	
1937	81.0	15,165	Good escapement.
1938	76.8	11,057	Fall pack curtailed by a strike.
1939	69.6	12,165	
1940	77.0	14,099	Heavy.
1941	73.6	26,924	Exceptional.
1942	66.7	24,136	Good.
1943	73.8	12,474	Light run.
1944	67.4	17,558	
1945	65.0	16,757	
1946	77.5	16,262	
1947	77.6	19,385	August good.
1948	75.6	19,485	Good run.
1949	78.6	11,162	
1950	77.5	11,034	
1951	70.2	10,560	
1952	37.5	9,512	Strike in August.
1953	55.1	8,120	August failure.
1954	54.2	6,146	August fishing has suffered severe damage.

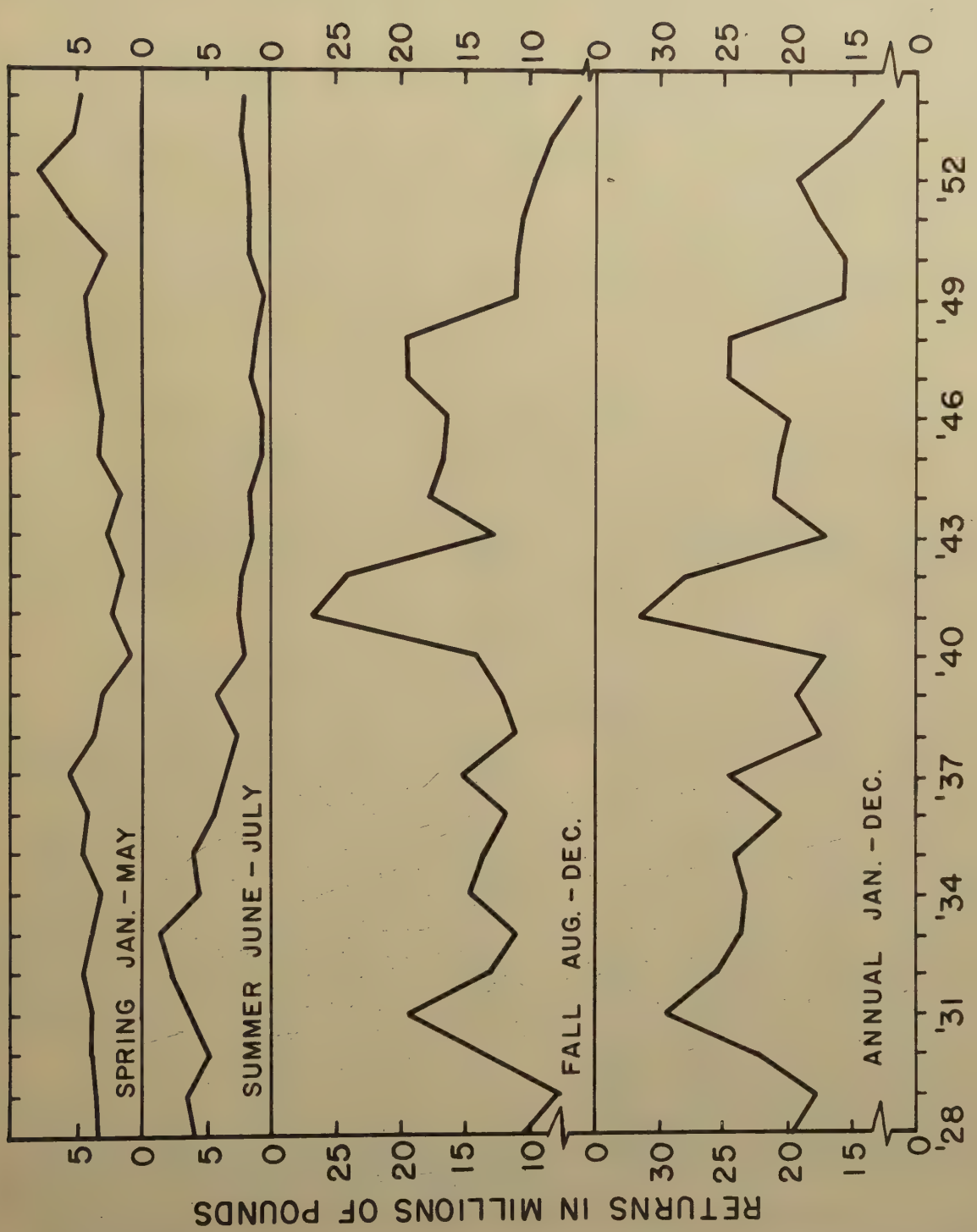

Figure 4.--Estimates of chinook salmon returns to the Columbia River derived as explained in the text for spring, summer, fall, and total season.

One such main-stem works is Rock Island Dam located 452 miles from the mouth of the Columbia River. Its 22 to 33-foot height was increased 20 feet in 1952. Yearly average counts of 12,000 chinooks were made through its fishways between 1934 to 1954. Further upstream from Rock Island Dam is Grand Coulee Dam which is 595 miles from the sea. It became a total block to salmon in 1939, but Rock Island counts averaging 8,500 chinooks for 6 years previous to its construction indicated that the area above Grand Coulee was no longer recipient of large runs. Further downstream is McNary Dam located 292 miles from the mouth of the Columbia River. Fish ladders were placed in operation at this dam in 1951 and power turbines were installed somewhat later so that returns from downstream migrants would not influence the period of comparisons in this report. Bonneville Dam, constructed in 1938, is a lower river dam which is located just above the boundary of tidal influence. Approximately 70 percent of the Columbia River chinooks must pass the fish-passage facilities placed there for them and the young must return the same route without special protection.

Indication of the effect of dams on survival of downstream migrants may be gained by comparing size of returns before and after the existence of Bonneville Dam. Since the effect on the smolts would be reflected in the adult migration after three years, 1941 was chosen as the division between returns instead of 1938. The estimate of spring abundance for the period between 1928 and 1941 averaged 3.5 million pounds compared with 4 million pounds between 1942 and 1954. The summer average for the period 1928 to 1941 was 5 million compared with 1.5 million pounds from 1942 to 1954. The fall return, 1928 to 1941, averaged 14 million pounds while the 1942 to 1954 return was also 14 million pounds. On an annual basis, returns averaged 22.5 million pounds before 1941 and averaged 19.5 million pounds after 1941. These data are presented in table 10.

Perhaps more conclusive information can be gained by comparing the returns with escapements, table 11. A lapse of four years is used between return and escapement on the basis of marking experiments which reveal a variety of maturing ages of chinooks but which are predominantly 4 and 5 years. In this regard, Mitchell G. Hanavan's Grand Coulee marking experiments reveal 62 percent four-year olds and 36 percent five-year olds caught in May of 151 marks collected in the fishery. June and July recoveries from the same experiments were 20 percent 3's, 42 percent 4's, 33 percent 5's, and 5 percent 6's from 1,153 marks collected in the fishery. The same type of experiment conducted by Harlan B. Holmes showed about two-thirds of the fall returns were 4-year olds from a collection of 2,677 marks. From these marking experiments a predominant 4 or 5-year cycle was determined for spring, summer, and fall from hatchery raised stock. Spring season ratio of return to escapement for the period before Bonneville Dam was 2.3:1 compared to 2.6:1 after the construction of Bonneville Dam. In the summer a return-escapement ratio of 4.4:1 existed before Bonneville construction and a ratio of 2.7:1 after. The fall return-escapement ratio before Bonneville Dam was 4.3:1 and 3.2:1 after. Combining all seasons the ratio of return to escapement was 3.8:1 before and 3.0:1 after construction of Bonneville Dam. These ratios were derived from data summarized in table 12.

DISCUSSION AND CONCLUSIONS

In an evaluation of the effect of water-use construction on chinook salmon in the Columbia River, Bonneville Dam was selected because of its strategic location in the main channel of the river and because it provides a greater number of years of successive fish-passage data for this study. In such an evaluation, it is pertinent to consider the ratios of return to escapement since these ratios are an indirect measure of mortality of young salmon passing over the dam. Examination of the data (table 12) shows that pre-Bonneville survival was better than post-Bonneville survival for the sum of the seasonal runs.

The before and after disparity was greatest for the summer runs, in which all fish spawn above Bonneville Dam, thus making their young vulnerable to injury in passing over the dam. The fall run, with 80 percent of the fish spawning above the dam, was intermediate in degree of change in survival rate. For the spring run, with only 67 percent of the fish spawning above the dam, there was an actual improvement in the survival rate. There is some indication of post-dam

Table 10.--Average returns of chinook salmon before Bonneville Dam (1928-1941) and after (1942-1954) in pounds.

Season	Before	After
Spring (January-May)	3,540,000	3,884,000
Summer (June-July)	5,053,000	1,578,000
Fall (August-December)	13,909,000	14,045,000
Total	22,502,000	19,507,000

Table 11.--Escapement1/ and return of Columbia River chinook salmon for three seasons each year.

	Escapement in 1000's of pounds					Return in 1000's of pounds			
Year	Spring	Summer	Fall	Annual	Year	Spring	Summer	Fall	Annual
1928	1,066	784	1,256	3,106	1932	4,519	7,581	13,132	25,232
1929	898	1,364	1,107	3,379	1933	3,808	8,593	11,157	23,558
1930	882	642	4,471	5,995	1934	3,079	5,480	14,726	23,285
1931	789	683	6,726	8,198	1935	4,554	6,054	13,467	24,075
1932	1,952	2,047	5,397	9,396	1936	4,075	4,498	11,930	20,503
1933	2,197	1,882	1,205	5,284	1937	5,446	3,724	15,165	24,335
1934	1,441	488	2,945	4,874	1938	3,628	2,800	11,057	17,485
1935	2,004	1,150	5,764	8,918	1939	3,034	4,018	12,165	19,217
1936	1,964	837	1,801	4,602	1940	921	2,076	14,099	17,096
1937	2,026	797	2,881	5,704	1941	2,160	2,618	26,924	31,702
1938	1,894	613	2,565	5,072	1942	1,632	2,187	24,136	27,955
1939	1,405	615	3,704	5,718	1943	2,917	1,682	12,474	17,073
1940	129	208	3,243	3,580	1944	1,780	1,900	17,558	21,238
1941	691	673	7,108	8,471	1945	3,311	781	16,757	20,859
1942	522	735	8,037	9,295	1946	3,088	739	16,262	20,089
1943	1,584	794	3,268	5,646	1947	3,736	1,537	19,385	24,658
1944	701	735	5,724	7,161	1948	4,022	1,078	19,485	24,585
1945	1,745	277	5,865	7,888	1949	4,148	675	11,162	15,985
1946	1,853	283	3,659	5,795	1950	2,939	1,775	11,034	15,748
1947	2,462	547	4,342	7,350	1951	5,494	1,800	10,560	17,854
1948	2,039	439	4,754	7,232	1952	7,765	1,975	9,512	19,252
1949	2,443	378	2,389	5,210	1953	5,057	2,291	8,120	15,468
1950	1,628	1,342	2,483	5,453	1954	4,601	2,080	6,146	12,827

1/ Escapement equals estimated return minus catch. Estimated returns from formula $\frac{f_2}{f_1} = \frac{p_2}{p_1}$ using base year 1947. Return in 1947 equals estimated escapement below Bonneville Dam plus Bonneville count plus catch below Bonneville Dam.

Table 12.--Comparative returns of chinook salmon before and after construction of Bonneville Dam.

Before Bonneville Dam:

Season	Sum of returns 1932-1941 (pounds)	Sum of escapements 1928-1937 (pounds)	Ratio return to escapement
Spring (January-May)	35,224,000	15,219,000	2.3:1
Summer (June-July)	47,442,000	10,674,000	4.4
Fall (August-December)	143,822,000	33,553,000	4.3
Total for year	226,488,000	59,456,000	3.8

After Bonneville Dam:

Season	Sum of returns 1942-1954 (pounds)	Sum of escapements 1938-1950 (pounds)	Ratio return to escapement
Spring (January- May)	50,490,000	19,096,000	2.6:1
Summer	20,500,000	7,639,000	2.7
Fall	182,591,000	57,141,000	3.2
Total for year	253,591,000	83,871,000	3.0

decline in survival rate for summer and fall, partially offset by an increase in spring survival rate.

Close observation of the annual abundance curve, figure 4, reveals a decline no more rapid after Bonneville Dam than before. The decline appears to be fairly constant throughout the 27 years. Observing the seasonal abundance curves: the spring season has improved since 1938; the summer abundance curve fell previous to Bonneville Dam and continued at a low level for a few years, then recovered noticeably; the fall abundance curve looked promising up to 1948, 10 years after Bonneville Dam, and then declined rapidly.

Briefly, the conclusions found in this study are the following:

(1) A 14 percent increase in spring returns averaging one-half million pounds per year after Bonneville Dam.

(2) A 70 percent drop in summer returns averaging 3-1/2 million pounds per year.

(3) The 1949 to 1954 fall run failures balancing the previously upswinging fall returns at 14 million pounds per year before and after Bonneville Dam.

(4) Average decline in total run of 13 percent or 3 million pounds after Bonneville Dam.

(5) Return-to-escapemement ratios for spring, summer, fall, and annual being 2.3, 4.4, 4.3, and 3.8:1 before Bonneville Dam and 2.6, 2.7, 3.2, and 3.0:1 after in that order.

(6) An improved spring return-escapement ratio and declining summer and fall return-escapement ratios after Bonneville Dam presented evidence that success corresponded with larger proportion of spawning occurring below the dam.

(7) The abundance curves representing 27 years of Columbia River chinook salmon returns (figure 4) reveal no special decline in trend after the construction date of Bonneville Dam.

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